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Tetsuji OMURA

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Examiner: Joseph L. Williams

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DECLARATION OF NORIKO KOMORIYA

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Sir:

Noriko Komoriya declares under penalty of perjury under the laws of the United States of America as follows:

1. I am a citizen of Japan currently employed at Frontier International Patent Office in Ota-shi, Gunma-ken, Japan. I have a good command both in English and Japanese languages.

2. I have translated Japanese Patent Application No. 2002-211870, and the translation is a literal translation of the Japanese patent application.

I declare under penalty of perjury under the laws of the United Stares that the foregoing is true and correct. Executed at Ota-shi, Gunma-ken, Japan, this 31st day of August, 2005.

Noriko Komoriya

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[Title of the Invention] Electroluminescent Display Device

[Claims]

[Claim 1] An electroluminescent display device comprising:

a device glass substrate provided with an electroluminescent element;

a sealing glass substrate attached to the device glass substrate;

a desiccant layer disposed on the sealing glass substrate; and

a stress buffering layer disposed between the sealing glass substrate and the desiccant layer and configured to relieve stresses generated in the desiccant layer by a difference in coefficient of thermal expansion between the sealing glass substrate and the desiccant layer.

[Claim 2] An electroluminescent display device comprising:

a device glass substrate provided with an electroluminescent element;

a sealing glass substrate attached to the device glass substrate;

a pocket portion formed on a surface of the sealing glass substrate by etching;

a desiccant layer disposed on a bottom of the pocket portion; and

a stress buffering layer disposed between the sealing glass substrate and the desiccant layer at the bottom of the pocket portion and configured to relieve stresses generated in the desiccant layer by a difference in coefficient of thermal expansion between the sealing glass substrate and the desiccant layer.

[Claim 3] The electroluminescent display device of claim 1 or 2, wherein the coefficient of thermal expansion of the stress buffering layer is higher than the coefficient of thermal expansion of the sealing glass substrate and lower than the coefficient of thermal expansion of the desiccant layer.

[Claim 4] The electroluminescent display device of claim 1 or 2, wherein the stress buffering layer comprises a layer made of aluminum.

[Claim 5] The electroluminescent display device of claim 1 or 2, wherein the stress buffering layer comprises a layer made of Alq3.

[Claim 6] The electroluminescent display device of claim 1 or 2, wherein the stress buffering layer comprises a layer made of polyimide.

[Claim 7] The electroluminescent display device of claim 1 or 2, wherein the stress buffering layer comprises a layer made of aluminum and a layer made of Alq3.

[Claim 8] The electroluminescent display device of claim 1 or 2, wherein the stress buffering layer comprises a layer made of aluminum and a layer made of polyimide.

[Claim 9] The electroluminescent display device of claim 1 or 2, wherein the stress buffering layer comprises a layer made of Alq3 and a layer made of polyimide.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The invention relates to a sealing structure of an electroluminescent display device for improving moisture resistance.

[0002]

[Background Art]

In recent years, organic electroluminescent (hereafter, referred to as EL) display devices with organic EL elements, which are self-emission elements, have been receiving attention as a new display device replacing CRT and LCD displays.

[0003]

Since the organic EL element is sensitive to moisture, in an organic EL display panel, a structure in which the organic EL element is covered with a metal cap or a glass cap coated with a desiccant has been proposed. Fig. 6 is a cross-sectional view showing

such a conventional structure of the organic EL display panel.

[0004]

A device glass substrate 70 has a display region having many organic EL elements 71 on its surface. The device glass substrate 70 is attached to a sealing glass substrate 80 for sealing the devices with sealing resin 75 made of an epoxy resin or the like. The sealing glass substrate 80 has a concave portion 81 (hereafter, referred to as a pocket portion 81) in a region corresponding to the display region, which is formed by etching. The pocket portion 81 is coated with a desiccant layer 82 for absorbing moisture on its bottom.

[0005]

Here, forming of the desiccant layer 82 on the bottom of the pocket portion 81 is for securing a space between the desiccant layer 82 and the organic EL element 71. This structure prevents the desiccant layer 82 from contacting the organic EL element 71 and thus from damaging the organic EL element 71.

[0006]

[Problem to be solved by the Invention]

It is necessary for the organic EL display panel to secure moisture resistance as well as reliability in resistance to temperature changes. We performed a temperature cycling test on organic EL panels, in which the temperature is raised and reduced in a cycle repeatedly. It was found that the desiccant layer 82 partially peeled off and came away from the sealing glass substrate 80 as shown in Fig. 7. It was also found that the desiccant layer 82 was partially peeled and torn and the torn portion 82A of the desiccant layer 82 is rested between the desiccant layer 82 and the device glass substrate 70. If these peeling off events happen, it is likely that the organic EL element 71 is damaged.

[0007]

[Means for solving the Problems]

We studied the above peeling off events and found that in the course of reducing the panel temperature after from an elevated temperature, a large stress contraction occurs in the desiccant layer 82 which has a higher thermal expansion coefficient than the sealing glass substrate 80. Especially, the difference in the thermal expansion coefficient causes

stresses to be focused onto the contact surface of the desiccant layer 82. When the stresses are higher than the adhesive strength between the desiccant layer 82 and the sealing glass substrate 80, the desiccant layer 82 peels off from the sealing substrate or tears.

[0008]

For solving the problem, the invention has the feature of providing the stress buffering layer between the sealing glass substrate and the desiccant layer for relieving the stresses generated in the desiccant layer by the difference in thermal expansion coefficient between the sealing glass substrate and the desiccant layer.

[0009]

[Description of the Invention]

Next, embodiments of the invention will be described with reference to the drawings in detail. First, a functional principle of the embodiments of the invention will be described with reference to Fig. 1.

[0010]

Fig. 1(a) is a schematic representation of a conventional structure, in which a desiccant layer 2 is directly coated on a bottom of a pocket portion provided on a surface of a sealing glass substrate 1. Suppose that the temperature of this structure is raised and then reduced. A thermal stress contraction occurs in the sealing glass substrate 1 and the desiccant layer 2. Since the coefficient of thermal expansion $\alpha 2$ of the desiccant layer 2 is generally higher than the coefficient of thermal expansion $\alpha 1$ of the sealing glass substrate 1, this difference generates stresses at a contact surface of the desiccant layer 2. If this stress is higher than the adhesive force between the desiccant layer 2 and the sealing glass substrate 1, the desiccant layer 2 peels off the sealing glass substrate 1.

[0011]

In this embodiment, a stress buffering layer 3 is inserted between the desiccant layer 2 and the sealing glass substrate 1, as schematically shown in Fig. 1(b). The coefficient of thermal expansion $\alpha 3$ of the stress buffering layer 3 is preferably higher than the coefficient of thermal expansion $\alpha 1$ of the sealing glass substrate 1 and lower than the coefficient of thermal expansion $\alpha 2$ of the desiccant layer 2 ($\alpha 1<\alpha 3<\alpha 2$).

[0012]

This condition makes the difference in the coefficient of thermal expansion between the desiccant layer 2 and the stress buffering layer 3 smaller. As a result, the stress generated in the desiccant layer 2 is lower than the stresses of the conventional structure without the stress buffering layer 3. This makes it difficult for the desiccant layer 2 to peel off the stress buffering layer 3. Furthermore, since the difference in the coefficient of thermal expansion between the stress buffering layer 3 and the sealing glass substrate 1 is made smaller, the stress buffering layer 3 also hardly peels off the sealing glass substrate 1. Accordingly, a sealing structure in which the desiccant layer 2 is prevented from peeling off is obtained.

[0013]

Next, a display device according to an embodiment of the invention will be described with reference to Fig. 2. A device glass substrate 100 has a display region having many organic EL elements 101 on its surface. The device glass substrate 100 is approximately 0.7 mm in thickness. The structure of the organic EL element 101 will be described below.

[0014]

The device glass substrate 101 is attached to the sealing glass substrate 200 for sealing the devices with sealing resin 102 made of an epoxy resin or the like. The sealing glass substrate 200 is formed with a concave portion formed by etching, i.e. a pocket portion 201 in the region corresponding to the display region. An Al (aluminum) layer 202 having a thickness of about 4000Å is formed on the bottom of the pocket portion 201 by, for example, an evaporation method, serving as a stress buffering layer. The Al layer 202 is coated with a desiccant layer 203 for absorbing moisture.

[0015]

The desiccant layer 203 is attached, for example, by coating on the Al layer 202 a solvent dissolved with powdered calcium oxide or barium oxide and resin as an adhesive, and then hardening the solvent by UV irradiation or heating. The desiccant layer 203 is, for example, 100 μm in thickness.

[0016]

Here, the coefficients of thermal expansion $\alpha 1$, $\alpha 2$, and $\alpha 3$ respectively corresponding to the sealing glass substrate 200, the desiccant layer 203 and the Al layer 202 are close to or below approximately 10×10^{-6}, approximately 100×10^{-6}, and approximately 30×10^{-6}, respectively. That is, the relationship of $\alpha 1<\alpha 3<\alpha 2$ is satisfied. The Al layer 202 has strong adhesion to the sealing glass substrate 200 and the desiccant layer 203. Therefore, the structure of Fig. 2 prevents the desiccant layer 203 from peeling off, according to the functional principle of the invention.

[0017]

Although the Al layer 202 is used as the stress buffering layer in this embodiment, Alq3 (8-tris-hydroxyquinoline aluminum) may be used instead. As long as the relationship of $\alpha 1<\alpha 3<\alpha 2$ is satisfied, the material of the stress buffering layer is not limited to Al, but other metals may be used.

[0018]

Furthermore, the material of the stress buffering layer is not limited to metals, but may be organic materials such as PI (polyimide). Although the coefficient of thermal expansion of PI is approximately 90×10^{-6} to 100×10^{-6} and is not lower than that of the desiccant layer 203 by a large amount, the adhesive force between the PI layer and the sealing glass substrate 200 is higher than that between the desiccant layer 203 and the sealing glass substrate 200. Therefore, the PI layer hardly peels off the sealing substrate 200 and the desiccant layer 203 on the PI layer hardly peels off, thereby relieving the stress generated by the thermal expansion.

[0019]

A display device according to another embodiment of the invention will be described with reference to Fig. 3. In this display device, the stress buffering layer has two layers of different materials. That is, a second stress buffering layer 205 is laminated on a first stress buffering layer 204, and the desiccant layer 203 is formed thereon. This enhances flexibility of designing stress buffering functions of the device.

[0020]

Specifically, in this embodiment, the stress buffering layer is formed by laminating any of two layers among the Al layer, the Alq3 layer and the PI layer, which are described

above. That is, the stress buffering layer has a laminating structure of the Al layer and the Alq3 layer, the Al layer and the PI layer, or the Alq3 layer and the PI layer.

[0021]

The stress buffering layer is not limited to the two-layered structure, but may be a lamination of three or more layers of different materials. Any of the structures can be adapted as long as the relationship of $\alpha1<\alpha3<\alpha2$ is satisfied when $\alpha1$, $\alpha3$, and $\alpha2$ are the coefficients of thermal expansion of the sealing glass substrate, the stress buffering layer, and the desiccant layer, respectively.

[0022]

Next, Fig. 4 is a plan view of a pixel of an organic EL display device, Fig. 5(a) is a cross-sectional view along line A-A of Fig. 4, and Fig. 5(b) is a cross-sectional view along line B-B of Fig. 4.

[0023]

As shown in Figs. 4 and 5, a pixel 115 is formed in a region surrounded by a gate signal line 51 and a drain signal line 52. A plurality of the pixels 115 is disposed in a matrix.

[0024]

An organic EL element 60 as a self-emission device, a switching TFT 30 for controlling a timing of supplying an electric current to the organic EL element 60, a driving TFT 40 for supplying an electric current to the organic EL element 60 and a storage capacitor are disposed in the pixel 115. The organic EL element 60 is formed of an anode 61 as a first electrode, an emissive layer 67 made of an emission material and a cathode 65 as a second electrode.

[0025]

The first switching TFT 30 is provided in a periphery of the intersection of the signal lines 51 and 52. A source 33s of the switching TFT 30 serves as a capacitor electrode 55 for forming a capacitor with a storage capacitor electrode line 54 and is connected to a gate 41 of the second driving TFT 40. A source 43s of the second driving TFT 40 is connected to the anode 61 of the organic EL element 60, while a drain 43d is connected to a driving source line 53 as a current source to be supplied to the

organic EL element 60.

[0026]

The storage capacitor electrode line 54 is positioned in parallel with the gate signal line 51. The storage capacitor electrode line 54 is made of chromium (Cr) or the like and forms a capacitor by storing an electric charge with the capacitor electrode 55 connected to the source 33s of the TFT 30 through a gate insulating film 12. A storage capacitor 56 is provided for storing voltage applied to the gate electrode 41 of the second driving TFT 40.

[0027]

As shown in Fig. 5, the organic EL display device is formed by laminating the TFTs and the organic EL element sequentially on a substrate 10 such as a substrate made of a glass or a synthetic resin, a conductive substrate or a semiconductor substrate. When using a conductive substrate or a semiconductor substrate as the substrate 10, however, an insulating film such as SiO_2 or SiN is formed on the substrate 10, and then the first TFT 30, the second TFT 40 and the organic EL element are formed thereon. Each of the two TFTs has a so-called top gate structure in which a gate electrode is placed above an active layer with a gate insulating film being interposed therebetween.

[0028]

The first TFT 30 as a switching TFT will be described first.

[0029]

As shown in Fig. 5(a), an amorphous silicon film (hereafter, referred to as an a-Si film) is formed on the insulating substrate 10 made of a silica glass, a non-alkali glass or the like by a CVD method or the like. The a-Si film is irradiated by laser beams for melting and recrystallization to form a poly-silicon film (hereafter, referred to as a p-Si film) as an active layer 33. On the active layer 33, a single-layer or a multi-layer of an SiO_2 film and an SiN film is formed as the gate insulating film 12. There are formed on the gate insulating film 12 the gate signal line 51 made of a metal having a high melting point such as Cr or Mo and also serving as a gate electrode 31, the drain signal line 52 made of Al, and the driving source line 53 made of Al and serving as a driving source of the organic EL element.

[0030]

An interlayer insulating film 15 laminated with an SiO_2 film, an SiN film and an SiO_2 film sequentially is formed on the whole surfaces of the gate insulating film 12 and the active layer 33. There is provided a drain electrode 36 by filling a contact hole provided correspondingly to a drain 33d with metal such as Al. Furthermore, a planarization insulating film 17 for planarizing a surface, which is made of an organic resin, is formed on the whole surface.

[0031]

Next, there will be described the second TFT 40 as a driving TFT of the organic EL element. As shown in Fig. 5(b), an active layer 43 formed by poly-crystalizing an a-Si film by laser irradiation, the gate insulating film 12, and the gate electrode 41 made of a metal having a high melting point such as Cr or Mo are formed sequentially on the insulating substrate 10 made of a silica glass, a non-alkali glass or the like. There are provided in the active layer 43 a channel 43c, and a source 43s and a drain 43d on both sides of the channel 43c. The interlayer insulating film 15 laminated with an SiO_2 film, an SiN film and an SiO_2 film sequentially is formed on the whole surfaces of the gate insulating film 12 and the active layer 43. The driving source line 53 connected to a driving source is disposed by filling a contact hole provided correspondingly to a drain 43d with metal such as Al. Furthermore, a planarization insulating film 17 for planarizing a surface, which is made of, for example, an organic resin or the like is formed on the whole surface. A contact hole is formed in a position corresponding to a source 43s in the planarization insulating film 17. A transparent electrode made of ITO (Indium Tin Oxide) and contacting the source 43s through the contact hole, i.e., the anode 61 of the organic EL element is formed on the planarization insulating film 17. The anode 61 is formed in each of the pixels, being isolated as an island.

[0032]

The organic EL element 60 has a structure laminated with the anode 61 made of a transparent electrode such as ITO (Indium Tin Oxide), a hole transport layer 62 having a first hole transport layer made of CuPc (Copper (II) phthalocyanine) and a second hole transport layer made of NPB (N, N'-Di (naphthalene-1-yl)-N, N' -diphenyl-benzidine), an

emissive layer 63 made of Alq3 containing a quinacridone derivative, an electron transport layer 64 made of Alq3, and a cathode 65 made of magnesium-indium alloy, Al or Al alloy, in this order.

[0033]

The planarization insulating film 17 is formed with a second planarization insulating film 66 thereon to prevent a short circuit between the anode and the cathode. The second planarization insulating film 66 is removed on the anode 61.

[0034]

In the organic EL element 60, holes injected from the anode 61 and electrons injected from the cathode 65 are recombined in the emissive layer and organic molecules forming the emissive layer are excited to generate excitons. Light is emitted from the emissive layer in a process of radiation of the excitons and then released outside after going through the transparent anode 61 and the transparent insulating substrate, thereby to complete a light-emission.

[0035]

[Effect of the Invention]

In the invention, the stress buffering layer is provided between the sealing glass substrate and the desiccant layer for relieving the stresses generated in the desiccant layer by the difference in thermal expansion coefficient between the sealing glass substrate and the desiccant layer, so that the desiccant layer etc can be prevented from peeling off. This can enhance the reliability of the organic EL display device in resistance to a temperature cycle

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 shows schematic cross-sectional views of an electroluminescent display device for explaining a functional principle of the embodiments.

[Fig. 2]

Fig. 2 shows a cross-sectional view of an electroluminescent display device according to an embodiment of the invention.

[Fig. 3]

Fig. 3 shows a cross-sectional view of an electroluminescent display device according to another embodiment of the invention.

[Fig. 4]

Fig. 4 shows a plan view of a pixel of the organic electroluminescent display device.

[Fig. 5]

Fig. 5 shows cross-sectional views of the pixel of the organic electroluminescent display device.

[Fig. 6]

Fig. 6 shows a cross-sectional view of an electroluminescent display device of a conventional art.

[Fig. 7]

Fig. 7 shows a cross-sectional view of the electroluminescent display device of the conventional art.

[Fig. 8]

Fig. 8 shows a cross-sectional view of the electroluminescent display device of the conventional art.

[Description of Numerals]

100 device glass substrate

101 organic EL element

102 sealing resin

200 sealing glass substrate

201 pocket portion

202 stress buffering layer

203 desiccant layer

[Document Name] Abstract

[Summary]

[Subject] The invention prevents a desiccant layer in an organic EL display panel from peeling off or tearing and enhances reliability in resistance to a temperature cycle.

[Solving Means] A device glass substrate 100 is attached to a sealing glass substrate 200 for sealing devices with sealing resin 102 made of epoxy resin etc. The sealing glass substrate 200 is formed with a pocket portion 201 by etching. An Al layer 202 having a thickness of about 4000Å is formed on a bottom of the pocket portion 201 by an evaporation method, serving as a stress buffering layer. A desiccant layer 203 for absorbing moisture is coated on the Al layer 202.

[Selected Figure] Fig. 2